MAPPING JETS AND EDDIES IN AN EASTERN BOUNDARY CURRENT

Adriana Huyer
College of Oceanic and Atmospheric Science
104 Ocean Admin Bldg
Oregon State University
Corvallis, Oregon 97331-5503
phone: 541/737-2108, FAX: 541/737-2064
email: ahuyer@oce.orst.edu

P. Michael Kosro
College of Oceanic and Atmospheric Science
104 Ocean Admin Bldg
Oregon State University
Corvallis, Oregon 97331-5503
phone: 541/737-3079, FAX: 541/737-2064
email: kosro@oce.orst.edu

Jack A. Barth
College of Oceanic and Atmospheric Science
104 Ocean Admin Bldg
Oregon State University
Corvallis, Oregon 97331-5503
phone: 541/737-1607, FAX: 541/737-2064
email: jbarth@oce.orst.edu

Robert L. Smith
College of Oceanic and Atmospheric Science
104 Ocean Admin Bldg
Oregon State University
Corvallis, Oregon 97331-5503
phone: 541/737-2926, FAX: 541/737-2064
email: rsmith@oce.orst.edu

Award Number N0014-92J1348

LONG-TERM GOAL

Our goal is to understand the spatial and temporal variability of mesoscale features such as jets and eddies in an eastern boundary current, and to relate these features to the larger-scale mean currents, the winds, and the biological productivity.

Report Documentation Page

Form Approved
OMB No. 0704-0188

1. REPORT DATE	2. REPORT TYPE	3. DATES COVERED
30 SEP 1997		**00-00-1997 to 00-00-1997**

4. TITLE AND SUBTITLE	5a. CONTRACT NUMBER
Mapping Jets and Eddies in an Eastern Boundary Current	5b. GRANT NUMBER
	5c. PROGRAM ELEMENT NUMBER
6. AUTHOR(S)	5d. PROJECT NUMBER
	5e. TASK NUMBER
	5f. WORK UNIT NUMBER
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) **Oregon State University,College of Oceanic and Atmospheric Sciences,104 Ocean Admin. Bldg.,Corvallis,OR,97331**	8. PERFORMING ORGANIZATION REPORT NUMBER
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)	10. SPONSOR/MONITOR'S ACRONYM(S)
	11. SPONSOR/MONITOR'S REPORT NUMBER(S)

12. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release; distribution unlimited

13. SUPPLEMENTARY NOTES

14. ABSTRACT

15. SUBJECT TERMS

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT **unclassified**	b. ABSTRACT **unclassified**	c. THIS PAGE **unclassified**	**Same as Report (SAR)**	**5**	

SCIENTIFIC OBJECTIVES

Our primary objectives are (1) to study the structure and characteristics of mesoscale jets and eddies over a large region spanning the California Current, in particular to determine the upper-ocean distributions of velocity, temperature, salinity, density and spiciness, kinetic and potential energy, relative and potential vorticity, and (2) to investigate the temporal evolution of the eddy/jet field during the spring/summer season, in particular to determine whether the main current axis and the eddies and jets propagate offshore and whether there is a change in the energy and vorticity fields. We are also investigating the relationship between the physical and biological characteristics of the jet/eddy field (with biological colleagues), and the temporal evolution of both large and small-scale features of the flow field (with other physical colleagues).

APPROACH

Our sampling approach was to survey a large area of the California Current using both a ship-borne Acoustic Doppler Current Profiler and a towed undulating SEASOAR vehicle containing Sea-Bird CTD sensors to measure currents, temperature and salinity in the upper 250 m of the ocean with a resolution of 2 dbar in the vertical, 2-3 km alongtrack, and 28 km between zonal sections. Through collaboration with colleagues, our Seasoar was equipped with an Optical Plankton Counter, a fluorometer and a PAR sensor. Large-area surveys were made in June-July and in August-September 1993, and each was followed by more detailed surveys of selected mesoscale features.

TASKS COMPLETED

Survey cruises were successfully completed in June-July and August-September 1993. The resulting data set includes two large-area surveys of the California Current, and additional surveys of an offshore-migrating cyclonic eddy, a counter-rotating eddy pair, and an inshore anticyclonic eddy. Seasoar data and conventional CTD data from both cruises have been reprocessed and carefully inspected to provide fully-calibrated, high-quality temperature and salinity data sets that have been summarized in a data report (Kosro et al., 1995). ADCP data have also been fully processed, and satellite AVHRR infrared images have been acquired from a collaborating colleague. Subsets of the data have been provided to biological and other physical colleagues and are being incorporated in their studies (e.g., Huntley et al., 1995; Ashjian et al., 1997) and some results have been incorporated in broader studies (e.g, Smith, 1996). Analysis of results from both the large-area and the smaller surveys is well underway and has resulted in several manuscripts (e.g., Huyer et al., 1997; Shearman et al., 1997).

RESULTS

A surface-intensified baroclinic jet was the dominant feature during both large-area surveys (Huyer et al., 1994; 1996, 1997). The current field was fairly simple in June, showing an equatorward surface jet with only one gentle meander, a nearly continuous poleward California Undercurrent near the continental margin, and two anticyclonic subsurface eddies offshore of the jet. By August meanders in the surface jet had strengthened, and eddies dominated the flow field. Large-scale trends in the water mass characteristics ("spiciness") along three isopycnal surfaces (26.4, 26.0 and 25.6 kg m^{-3}) show that temperature and salinity tend to increase towards the equator and towards

shore, consistent with poleward advection along the continental margin. Local minima in spiciness tend to coincide with the equatorward surface jet. Local maxima in spiciness are associated with subsurface anticyclonic eddies which have a core depth of about 150 m, and seem to originate in the California Undercurrent over the continental slope at local latitudes. We identified several different anticyclonic eddies, each with different water-mass characteristics; all of the eddies we observed had diameters larger than the baroclinic radius of deformation. Water-mass characteristics and migration rates of the anticyclonic eddies are consistent with formation over the continental margin within the preceding 6-8 months.

Analysis of the ADCP velocity data from the large-area surveys (Kosro et al., 1996) shows a clear and coherent signal in the ageostrophic component of the near-surface currents. Stream-functions of the directly measured currents at 25m and 200m, and the difference between them, were computed for both surveys from the ADCP currents using objective analysis (Bretherton et al., 1976, Walstad et al., 1991). Comparison of the difference streamfunction with the dynamic topography at 25m relative to 200m shows that the directly measured shear closely follows geostrophy. The dominant difference is that the ADCP streamfunction has higher values in the north and lower values in the south. Maps of the residual between the ADCP streamfunction of the directly measured flow at 25m relative to 200m and the dynamic topography show a north-south gradient, which corresponds to an ageostrophic current to the west, for both surveys. Similar maps of residuals for the 41m/200m topography show the westward flow penetrating to 41m in the June survey, but not in the August survey (which had weaker winds). To examine the vertical structure of the ageostrophic component, the objectively mapped dynamic topography was used to calculate geostrophic currents for each ADCP sample site, and these geostrophic current profiles were subtracted from the measured currents to provide vertical profiles of the ageostrophic flow. These were averaged over each survey. Hodographs of these averages for both surveys show that the ageostrophic component of the near-surface current lies to the right of the wind, and decreases with depth; the penetration depth of the ageostrophic flow is shallower during the cruise with weaker winds.

A cyclonic eddy which originated off Point Arena in April 1993 and migrated west-south-westward at 0.05 m/s was sampled several times. The dynamics of this eddy has been analyzed (Shearman et al., 1996, 1997) by means of the Q-vector form of the quasi-geostrophic omega equation (Hoskins et al., 1978). The eddy survey covered a 110 by 80 km region, with Seasoar/ADCP sections ~10 km apart. The density data from Seasoar were detided by harmonic analysis, averaged vertically into 10m bins, and smoothed horizontally onto a 2x2 km grid using objective analysis (Bretherton et al., 1976). Smoothed density data from different levels were integrated vertically and combined with a streamfunction calculated from the ADCP velocities at 200m to provide an estimate of the absolute dynamic topography. Geostrophic velocities within the jet have maximum speeds of ~50 cm/s. Relative vorticities within the jet are large, ranging from $-0.8f$ to $1.2f$, where f is the local Coriolis parameter. The diagnosed vertical velocity field is characterized by two length scales: a large (~75 km) pattern where there is downwelling upstream and upwelling downstream of the cyclonic bend, and smaller patches arrayed along the jet core with diameters of 20-30 km. Geostrophic streamline analysis of vertical velocity indicates that water parcels make net vertical excursions of 20 to 30 m over 2-3 days, resulting in net vertical velocities of 7-15 m d^{-1}. These vertical displacements are sufficient to move waters into and out of the euphotic zone, and thus are likely to affect the primary productivity.

IMPACT/APPLICATION

Our surveys show clearly that eastern boundary currents are not "broad, weak equatorward flows", but instead are sites of intense interactions between jets, eddies, coastal currents, and the continental margin. There is strong evidence that both cyclonic and anticyclonic eddies are generated inshore along the continental margin and migrate out to sea. The combination of closely spaced Seasoar and ADCP measurements provides good estimates of the ageostrophic component of near-surface currents. Vertical displacements associated with eddy/jet interactions are estimated to be >30 m, sufficient to move water parcels into and out of the euphotic zone and thus affect primary productivity.

TRANSITIONS

RELATED PROJECTS

An ongoing study of the shelf/slope circulation off southern Oregon ("Separation of a coastal jet: A link between the coastal and adjacent deep ocean", PIs: J. A. Barth, R. L. Smith) has resulted in three survey cruises and drifter data providing relevant upstream and inshore information that will aid in understanding the dynamics of the jets and eddies of the California Current.

REFERENCES

Bretherton, F. P., R. E. Davis and C. B. Fandry, 1976.A technique for objective analysis and design of oceanographic experiments applied to MODE-73. Deep-Sea Research 23:559-582.

Hoskins, B. J., I. Draghici, and H. C. Davies, A new look at the omega-equation. Quart. J. R. Met. Soc., 104, 31-38, 1978.

Huntley, M. E., M. Zhou and W. Nordhausen. 1995. Mesoscale distribution of zooplankton in the California Current in late spring, observed by Optical Zooplankton Counter. J. Marine Res., 53, 647-674.

Huyer, A., J. A. Barth, P. M. Kosro and R. L. Smith. 1994. Surveys of the California Current: Large-Scale Coverage with Mesoscale Resolution. Abstract only. EOS, Trans. Amer. Geophys. Union, 75(3), Supplement, 140.

Huyer, A., J. A. Barth, P. M. Kosro, R. K. Shearman and R. L. Smith. 1997. Upper-ocean water mass characteristics of the California Current, summer 1993. Deep-Sea Research. In press.

Kosro, P. M., J. A. Barth, J. Fleischbein, A. Huyer, R. O'Malley, R. K. Shearman and R. L. Smith, 1995. SeaSoar and CTD observations during EBC cruises W9306A and W9308B June to September 1993. Coll. Ocean. Atmos. Sci., Ore. State Univ., Data Rep. 160, Ref. 95-2, 393 pp.

Kosro, P.M., A. Huyer, R.L. Smith, J. A. Barth, S.D. Pierce, P. T. Strub, S. R. Ramp, "Studies of the California Current and Undercurrent", Benguela Dynamics Symposium, University of Cape Town, South Africa, November 1996.

Shearman, R. K., J. A. Barth, and P.M. Kosro. 1996. Diagnosis of Three- Dimensional Circulation: Results from the Eastern Boundary Current Program. Transactions, Amer. Geophys. Union, EOS, 77(3), Ocean Sciences Meet. Suppl., OS131.

Shearman, R. K., J. A. Barth and P. M. Kosro. 1997. Diagnosis of the three- dimensional circulation associated with mesoscale motion in the California Current. J. Phys. Oceanogr., submitted.

Smith, R.L. 1995. The Physical Processes of Coastal Upwelling Systems. In: Upwelling in the Ocean: Modern Processes and Ancient Records, edited by C. P. Summerhayes, K.-C. Emeis, M. V. Angel, R. L. Smith and B. Zeitschel. John Wiley and Sons, p. 39-64.

Walstad, L.J., J.S. Allen, P.M. Kosro and A. Huyer, 1991. Dynamics of the coastal transition zone through data assimilation studies. J. Geophys. Res. 96:14959-14977.

_